

Back to the Future

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Back to the Future: A Backcasting based Approach to Planning for an Energy System Transition in the Danish Region of Zealand

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Abstract: *The article presents a backcasting-based approach to energy planning, and applies this to a case study on the development of an action plan aimed at the complete transition to renewable energy in the Danish Region of Zealand. Through the application of a systemic and target-oriented approach, a step-by-step backcasting methodology is outlined and utilized. The article highlights the value of the backcasting approach in addressing key limitations of forecasting based planning approaches and underlining the need for flexibility concerning the deep uncertainty associated with energy futures.*

Key words: *Climate change, renewable energy, energy system transition, planning, backcasting, Local Government*

1. Introduction

Mitigating global climate change will be one of the defining challenges for humanity in the twenty-first century. As the energy system is the primary cause of greenhouse gas emissions, as well as a key means of mitigation, decarbonising our energy supply is of critical importance for solving this challenge (Edenhofer et al, 2011: 3). A low carbon energy supply can be achieved through an energy system transition, defined as a change in the composition, or structure, of the energy supply from one pattern of energy provision to another; in this case from a system based on fossil fuels to one based on renewable sources of energy (Smil, 2010: vii). A transition to a renewable energy supply is not only desirable but also eventually unavoidable given the finite nature of fossil fuel reserves; however, it is considerably

more difficult than is commonly realized. The scale and magnitude of the shift, as well as the character and distribution of the available resources, implies that a large-scale adoption of renewable sources of energy would have to be accompanied by a fundamental reshaping of the energy infrastructure (Smil, 2010: 108, 119). In doing so, it is argued that Local Governments (LGs) could provide a significant contribution in facilitating this transition by acting as a catalyst in linking global targets with local implementation (Fudge & Peters, 2009: 103ff). It is the contention in this article that facilitating this change may gain considerable traction by applying a novel approach to LG energy planning based on the concept of backcasting.

2. New Approach to Local Energy Planning

Local governments in Denmark have been tasked with energy planning since 1979, when the first heat planning policy was enacted. It introduced a rigorous and effective planning system, which was, however, limited to planning for local heat supply. Throughout the 1990's and 2000's this system has been simplified and liberalized, effectively limiting the role of local governments to one of approving energy infrastructure projects (LGDK & DEA, 2010: 23ff). However, faced with the necessity of decarbonising our energy supply, there is a need for a reform of this planning approach. *"As our targets change, so too must our responses."* (Esty & Chertow, 1997: 1). The key aspect of such a new approach is comprehensiveness. We need an approach that includes all aspects of the energy chain, not simply energy supply, an approach that integrates the different energy sectors, long-range change with short-term action, as well as the global, national and local actors in facilitating change. *"We see a need for a 'systems' approach to policy built in rigorous analysis, an interdisciplinary focus, and an appreciation that context matters."* (Esty & Chertow, 1997: 4). A recent proposal by Local Government Denmark (LGDK) and the Danish Energy Authority (DEA) calls for an expansion of local planning efforts to encompass a 'strategic energy plan', in which municipalities plan for an optimal interplay between consumption and supply, while optimizing the use of energy resources. In doing so, LG should include the entire energy chain, several energy sectors (heating, cooling and electricity) as well as a long-range view of transitioning towards a carbon free energy supply (LGDK & DEA, 2010: 7).

We find that two aspects are central in this re-orientation: A broadening of the scope as well as a more target-oriented planning approach (LGDK & DEA, 2010: 26f). The change in scope points to a systems approach (as opposed to a view of individual technologies, sectors or parts of the energy chain) as a necessary precondition of understanding long-term technical change (Scrase & MacKerron, 2009: 91). The need for a target-oriented approach is self-evident, as planning based on the goal of decarbonising our energy supply is inherently a target-oriented task. We believe that backcasting may act as an appropriate tool in long-term planning for system transition. In the following we will start by

outlining the planning approach and subsequently apply it to a case study of the Danish Region of Zealand. Finally, we will discuss the added value of the proposed planning approach in facilitating systemic change.

3. Backcasting in Energy Planning

Backcasting emerged as a distinct approach to future studies in the 1970's, however somewhat similar approaches to exploring normative futures preceded it, generally known as normative forecasting (Vergragt & Quist, 2011: 748). Jantsch distinguished between normative and exploratory forecasting arguing that a normative approach should be used to set goals for technological development, as for e.g. the Apollo space programme (Jantsch, 1967: 29ff; Vergragt & Quist, 2011: 748). The emergence of future studies and scenario planning are generally attributed to the RAND Corporation, working with the American defence establishment in the 1940's and 50's (Herrmann, 2011: 91; Lindgren & Bandholm, 2009: 37), yet one could argue that tracing the origins of target oriented planning is a somewhat difficult task. This however cannot be said for the specific concept of backcasting. John B. Robinson coined the term 'Energy Backcasting' in 1982, proposing a novel method of energy policy analysis, in which he credits Amory Lovin's work with 'backwards-looking-analysis' in developing soft energy paths throughout the 1970's (Robinson, 1982a: 337; Lovins, 1977: 65; Quist & Vergragt, 2006: 1029). This early work in the USA (Lovins) and Canada (Robinson) was supplemented by the simultaneous development of a somewhat different typology in Sweden (Dreborg, 1996: 814; Vergragt & Quist, 2011: 748). Following the early development of backcasting for energy studies and policy analysis, the focus of backcasting research was shifted towards the application for sustainability studies in the 1980's and subsequently towards strategic backcasting and stakeholder participation throughout the 1990's (Herrmann, 2011: 105; Vergragt & Quist, 2011: 748; Quist & Vergragt, 2006: 1029ff). In a Danish context, the majority of the writing on the topic originated from the Academy for Future studies in the late 1990's and early 2000's, however some articles predate that quite considerably (Jansen, 1987; Jansen, 1999; Jansen, 2003; Nielsen, 2000).

Backcasting can be defined as the creation of a desir-

able future vision, and then looking back at how this desirable future can be achieved (Quist & Vergragt, 2006: 1028). *“The major distinguishing characteristic of backcasting analyses is a concern not with what futures are likely to happen, but with how desirable futures can be attained.”* (Robinson, 1990: 822). As such backcasting is explicitly normative with a focus on problem-solving, and developed with the purpose of integrating a systemic perspective and long time spans making it very well suited for dealing with the high complexity and uncertainty associated with energy planning (Herrmann, 2011: 102f; Vergragt & Quist, 2011: 747). Backcasting can be distinguished from other future study approaches based on the questions they ask and the futures they study. We can distinguish between predictive, explorative and normative techniques studying probable, possible and preferable future. Predictive scenarios study ‘what will happen’, explorative scenarios study ‘what can happen’ and normative scenarios ask ‘how a certain target can be reached’ (Höjer et al., 2008: 1959f; Börjeson et al., 2006: 725ff). Traditional forecasting applies a predictive scenario approach, whereas backcasting, as mentioned, applies a normative approach (Höjer et al., 2008: 1960; Vergragt & Quist, 2011: 748).

Utilizing backcasting as an analytical approach requires an operationalization of these general principles into a step by step methodology. Robinson established one such sequential six-step approach in 1982 based on the principles established by Lovins and then further elaborated the approach in

a 1990 publication (Quist & Vergragt, 2006: 1029; Robinson, 1982a: 339; 1990: 824). Subsequently a number of alternative approaches have been proposed resulting in a typology toolbox of backcasting methods, a selection of which has been summarized in the table 1 below.

As can be seen from the table, the majority of approaches are somewhat similar, albeit with some variations. As is inherent in the nature of the concept, the majority of approaches start by specifying objectives followed by a description of the current day system. Some approaches, in particular the Tyndall decarbonisation scenarios, start by defining the strategic objective, yet defer the characterisation of future energy demand and supply to follow the description of the current system (Mander et al., 2008: 3758). This appears to be a useful approach as the definition of strategic objectives should precede the mapping of the present day system, however defining the specificities of demand and supply is challenging without knowledge of the current system. Following the goal specification and baseline description, the majority of approaches utilize a characterisation of the target system followed by a description of the pathway towards it. The particularities of these steps vary quite considerably, from the techniques developed for municipal supply companies targeting their strategic choices (Herrmann), to the techniques focused on overall system development (Tyndall). The final step varies even more, where some explore implications and impacts, others develop policies and review the procedure and some simply identify strategic path-

Table 1: Typology of backcasting approaches.

Robinson	Anderson	The Natural Step	Tyndall	Herrmann
1. Determine objectives	1. Specify the strategic objectives	1. Awareness	1. Specify the strategic objective	1. Definition of future landing place
2. Specify goals constraints and targets	2. Describe present generation and consumption	2. Baseline	2. Describe the present energy system	2. Description of future vision
3. Describe present system	3. Choose end-point year	3. Visioning	3. Characterise energy demand	3. Analysis of the status quo
4. Specify exogenous variables	4. End-use analysis	4. Setting and managing priorities	4. Define an energy supply system	4. Derivation of external crossroads and internal milestones
5. Undertake scenario analysis	5. Supply analysis		5. Step back in time from defined end-point (describe the transition).	5. Identification of strategic pathway
6. Undertake impact analysis	6. Policy development		6. Explore implications	
	7. Review procedure			

Robinson (1990: 824), Anderson (2001: 615ff), Cook (2004: 40ff), Mander et al. (2008: 3758) & Herrman (2011: 109, 127-129).

ways and priorities as the final step.

The differences in the overall approach of the different backcasting methodologies can be partially attributed to the differences in applicability, as e.g. the Natural Step framework and Herrmann's approach have primarily been developed for organisations and energy companies (Herrmann, 2011: 106), these approaches focus on developing strategic plans for particular groups of actors. Additionally Anderson's approach is focused on the electricity industry, whereas the Tyndall and Robinson approaches utilize a full system analysis. Finally temporal development and refinement has a role to play, as is evident in the development of Robinson's own methodology (Robinson, 1982a; 1990).

Informed by the survey in table 1, the following analytical approach has been developed for constructing systemic, long-range low carbon supply plans, primarily informed by the Tyndall approach, as it has the closest applicability to the task at hand (Mander et al., 2008). The analytical approach is illustrated in figure 1 below.

When applying this approach the first step entails the formulation of the ideal state for the system under study, i.e. the transitional goal. Subsequently the second step entails a mapping of the current state of the energy system followed by a thorough mapping of transitional preconditions consisting of forecasted energy demand, as well as mapping the possibilities for energy savings and efficiency measures on the one hand, and available energy resources and technologies on the other. The fourth step entails

the formulation of the target state, or transitional results, of the system in question, followed by the formulation of the specific transitional steps in arriving at the target. With the purpose of illustrating this approach, as well as assessing its applicability; we have applied it to a case study of the Region of Zealand (DK) to which we now turn¹.

4. Sustainable Energy Action Plan for the Region of Zealand

The Region of Zealand contains 17 municipalities located in the eastern part of Denmark. The regional view was chosen to produce a sufficiently large and diverse sample ensuring a variation in urban and rural areas as well as a spread of energy consuming activities such as agricultural, industrial and residential usage. In this way applying the approach to a regional scope, instead of e.g. a municipal one, ensures a broad composition of planning challenges for assessing the tools applicability, and yet the regional view, as opposed to e.g. a national scope, is sufficiently small to allow a discussion of particular contextual challenges as opposed to accumulated totals.

Additionally it should be emphasized that the scope of the system under study has been defined based on administrative structures and not actual system boundaries. As such the system presented is theoretical as e.g. the electricity system and parts of the district heating system is connected across regional borders with the capital region of Denmark, and as transportation patterns cross borders as well. The system scope is based on a consumption account-

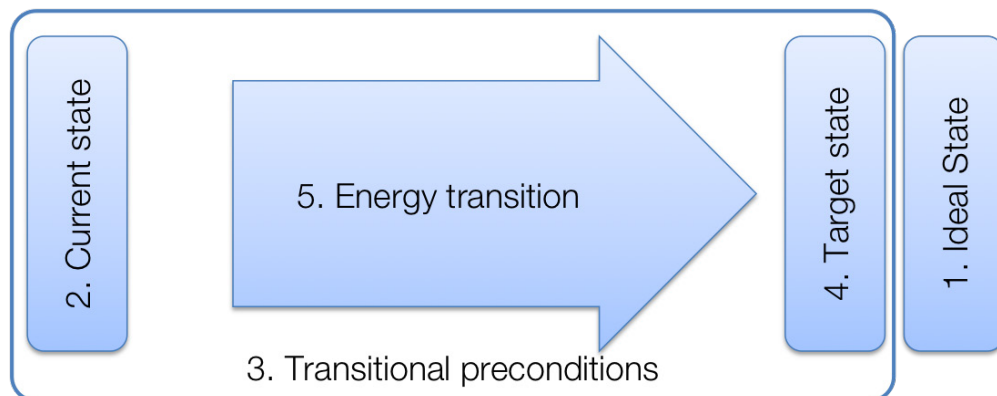


Figure 1: Analytical approach.

Starting by defining the ideal future state, then mapping the current state and transitional preconditions, followed by backcasting towards the ideal future state, arriving at the target state. Adapted from Damsø, 2012.

ing principle in which energy consumption and associated GHG emissions are attributed to energy consumers (households, industries etc.) within the region (Munksgaard & Pedersen, 2001: 328). Based on energy consumption within the region, the system scope is delimited at the 'first order of representation', as it includes emissions upstream from electricity and heat production but not life cycle emissions in obtaining the fuels utilized (Blok, 2007: 132f). Additionally the system can be considered theoretical in the sense that the region does not have any significant formal authority with regards to energy planning, and as such the plan would have to be enacted through a range of other actors, including municipalities, utilities and state agencies.

Looking first to identify the *ideal state*, the target for the transition is an energy supply solely based on renewable energy in 2050, thereby reducing the GHG emissions in line with the recommendations from the International Panel On Climate Change (IPCC)(IPCC-SYN, 2007: 36, 67). Additionally this supply should be based on local production

of renewable energy, i.e. the region should be self-sufficient with renewable energy resources. These objectives are supplemented by a set of requirements and optimization criteria guiding the analysis that will be discussed where relevant in the following.

The second analytical step entails the mapping of the energy system in its *current state* for the base year (2008) accounting for all energy consumption and production as well as the associated Greenhouse Gas (GHG) emissions for the region. As the system scope is based on a consumption accounting principle, the system has primarily been mapped following energy consumption upstream. However for the collective utility supply systems (district heating and electricity production) a production based approach to mapping the energy chain has been utilised due to a higher data quality. The energy balance (in Peta Joule (PJ)) is illustrated in the figure 2 below.

The single largest energy source in the region is oil, primarily based on the large consumption for

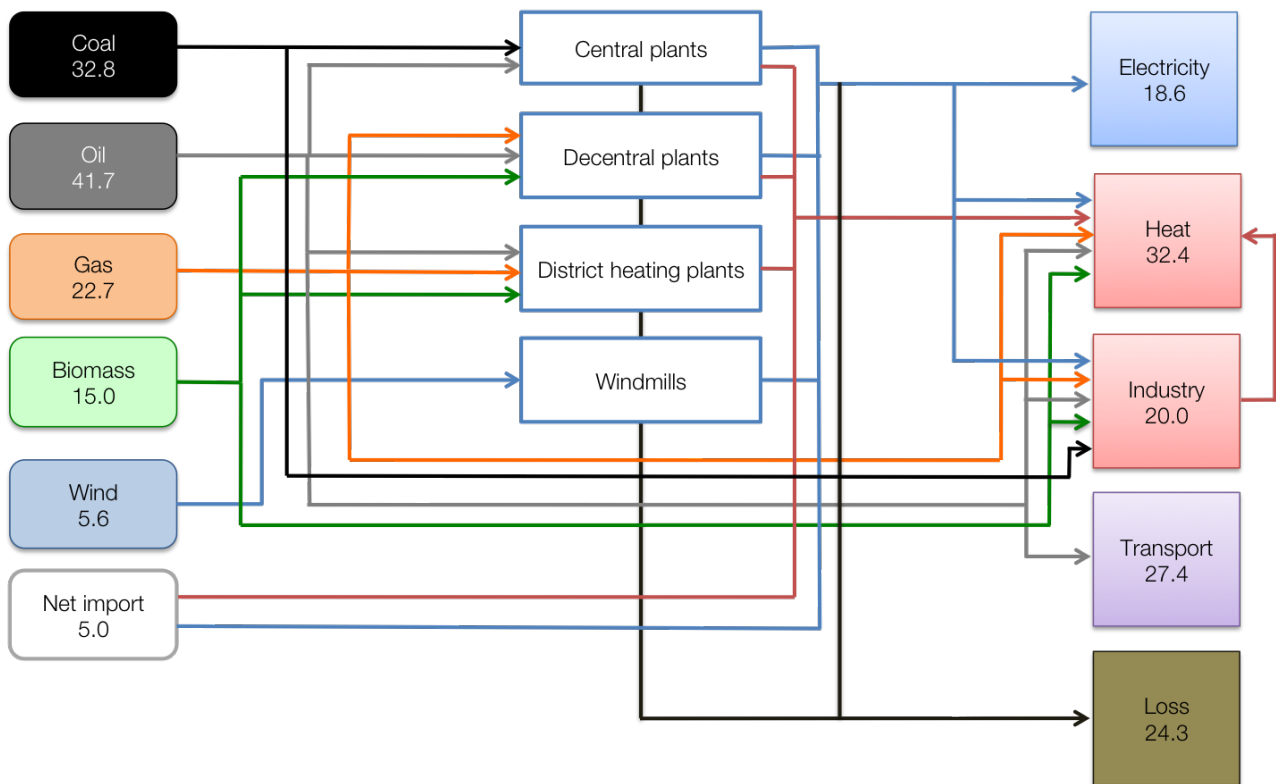


Figure 2: Energy balance for the Region of Zealand in 2008 (PJ).

The figure summarizes the energy flows in the region for 2008, from resource input, through conversion to final energy demand. In all thermal conversion processes there is a loss of useful energy illustrated with the box 'loss' in the figure. Revised and adapted, based on Damsø (2012: 38).

transportation, followed by coal primarily utilized for electricity production. The largest energy consumer is the heating sector, accounting for large shares of the biomass, natural gas and oil consumption. Additionally the region was a net importer in 2008, primarily through a large import of 4.2 PJ electricity and a smaller import of 0.8PJ district heating through the large district heating system in the greater Copenhagen area. The Region of Zealand had a total GHG emission of 9.5 Mt of CO₂-equivalents (eq.), including emissions from non-energy sources, such as agriculture, industrial solvents and land-use change. Roughly 80% of emissions were caused by energy related sources and the remaining 20% from non-energy related sources (Damsø, 2012: 38).

In the third step the particular *transitional preconditions* for the transition under study are identified. This involves firstly an analysis of the energy demand, involving a baseline projection of the demand for energy services from 2008 to 2050 followed by an identification of the potential for energy savings and efficiency measures. Energy demand is expected to almost double if left unchecked increasing from 96 PJ in 2008 to 187 PJ in 2050. However there is a significant potential for efficiency and savings measures, which if implemented properly can reduce the expected energy demand to 75 PJ in 2050 (Damsø, 2012: 49). Secondly mapping the transitional

preconditions involves identifying the renewable energy resources and technologies available for the energy supply system in 2050. This has been done for all known renewable energy resources, of which some however have only a negligible or uncertain potential (hydropower & ocean energy) and others no meaningful way of quantitatively assessing the available potential (geothermal and ambient heat), for which ability to utilize the energy is the only relevant limitation in the region (Damsø, 2012: 50; DCCCP, 2010: 29f, 40). For the remaining group there is an available potential of 129 PJ renewable energy resources in 2050. With regards to biomass the study precludes the possibility of biomass import due to the risk of direct and indirect land-use change as a result of its production. Additionally the utilization of biomass for energy purposes has been limited to the amount that can be produced annually, i.e. within renewable limits. Food production is kept at current levels releasing land area through increasing productivity in agriculture, some of which is assigned to nature conservation and the remaining fraction utilized for dedicated bioenergy production (Damsø, 2012: 57, Jørgensen et al., 2008; Dalgaard et al., 2011: 3193f). The projected development in energy consumption and the available renewable energy resources have been summarized in figure 3 below.

As can be seen from the figure, achieving the po-

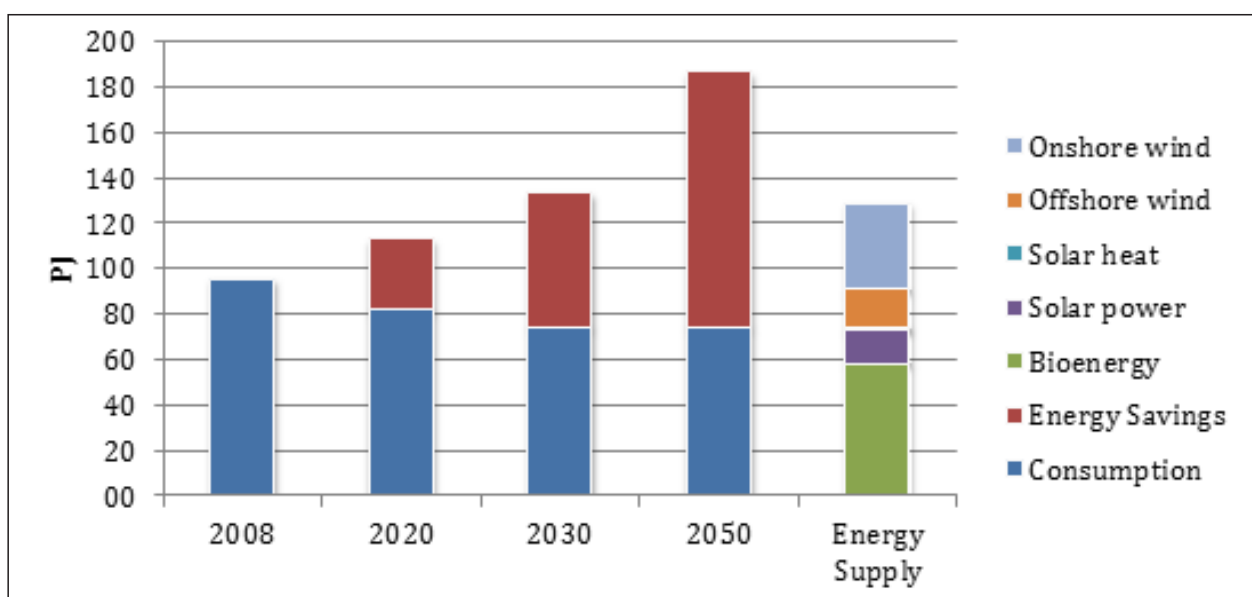


Figure 3: Projection of energy demand, the potential reductions from energy efficiency measures and available renewable energy resources in 2050 (PJ). Adapted from Damsø (2012:43-49, 69).

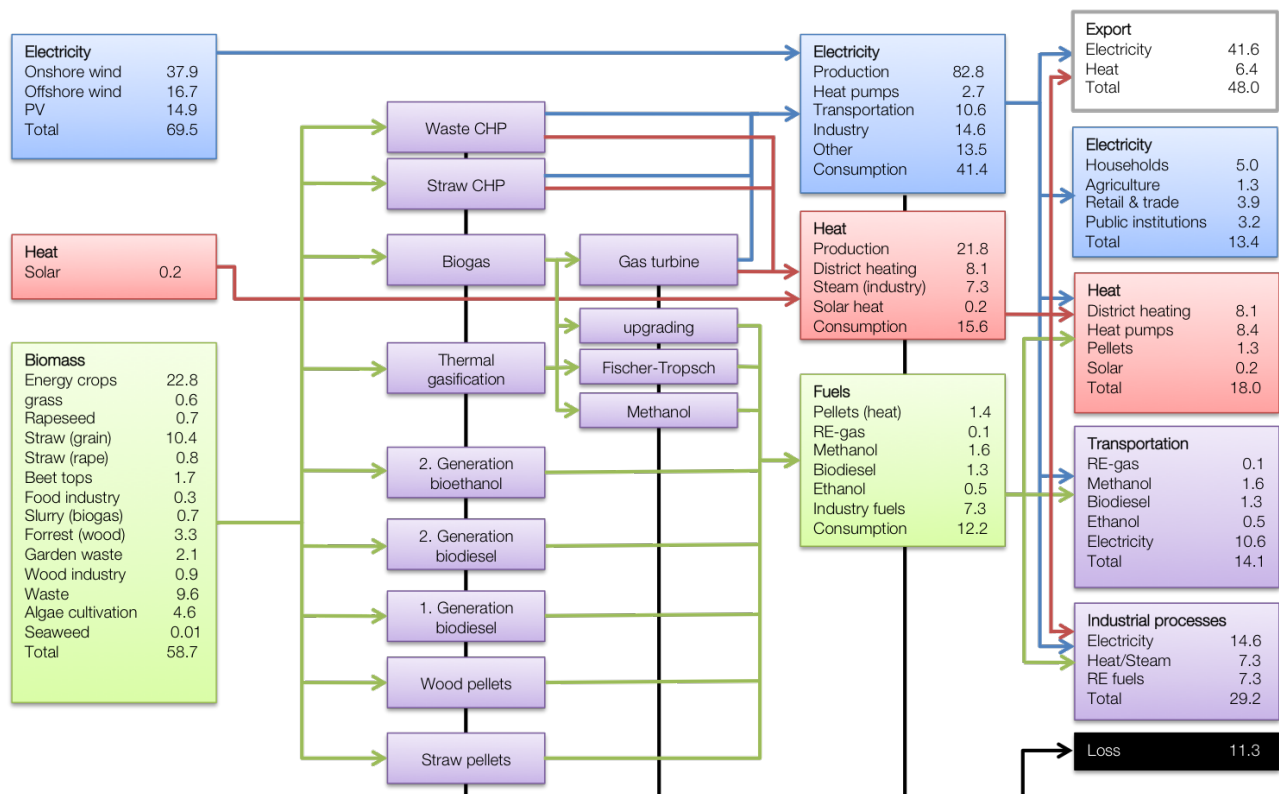


Figure 4: Energy balance for the target state in 2050 (PJ). Adapted from Damsø (2012: 119).

tential energy savings will be key if the region is to supply itself with renewable energy. Subsequently the available energy potential seems sufficient to supply the remaining demand, however the character of the energy sources as well as conversion losses complicates the task at hand.

The fourth step involves defining an energy balance for the **target state**. In doing so we apply a procedural approach by which the task is divided into stages and steps as a way of coping with the complexity of designing a future energy system. The design process has been divided into the following steps:

1. First, allocation of the autonomous elements (i.e. wind power being used for electricity consumption)
2. Second, the factors considered as given (manure treated for biogas production, municipal solid waste for incineration) are assigned conversion routes before
3. Third, assessing and discussing the remaining flexible elements (i.e. bioenergy, district heating and thermal electricity production) (Damsø, 2012: 73).

These are assigned to different conversion routes

based on achieving the highest available overall efficiency in supplying the specific energy demand, however with the possibility of waiving that principle with reference to increasing the stability of the energy system or overall flexibility and robustness of the system transition (Rosenhead, 2001: 181). The resulting energy balance is presented in figure 4 below.

As can be seen from the figure there is a significant surplus of 41.6 PJ electricity production from, especially, onshore wind power that can be supplied to the Capital Region. 58% of the bio energy is converted into gaseous form supplying the transport sector, the industry and especially combined heat & power production meeting the demand for electricity and district heating not covered by the variable sources. As there is a large excess heat and electricity production, this process has a significant resource surplus, allowing for the possibility of reducing overall efficiency to increase system flexibility, e.g. by increasing individual heat and electricity production as opposed to Combined Heat & Power (CHP) units or recycling municipal solid waste instead of incinerating it. In this way the overall system efficiency can be reduced in dealing with unforeseen challenges. Following the system design for the 2050 case **tran-**

sition of the system from the current state towards this desired end state should be outlined. For heating, the transition process involves the achievement of large energy savings in the existing building stock, an expansion of the district heating system as well as a conversion of the remaining individual heating in rural areas to ambient heat using electric heat pumps, supplemented by wood pellets and solar heating (Damsø, 2012). In the transport sector, the most significant change is from a fuel-based to an electricity-based infrastructure. 75% of all energy supplied for transport will be in the form of electricity resulting in significant energy savings and the remaining modes of transport will be supplied by a range of biofuels (DEA, 2008; Arvizu et al., 2011). With regards to energy for industrial processes the major shift will be from the use of primary (fossil) to secondary (electricity & heat) energy carriers for the majority of energy consumption, and a range of bioenergy based fuels for the remaining share (Arvizu et al., 2011; Damsø, 2012: 94). Electricity consumption exhibits a small increase of 11%, however as all other sectors undergo a shift towards utilizing electricity as the primary energy carrier, total consumption is expected to rise 122% (Damsø, 2012: 95). Additionally the available energy sources for supply may be ample, but also fluctuating and difficult to store, resulting in system balance being the key challenge of the future. This is done through a combination of flexible consumption, storage, increased transmission capacity and flexible peak power production based on biomass based gas (Risø-DTU & Ea, 2010; Damsø, 2012). Finally with regards to bioenergy, the available potential has a number of cross-cutting tasks, in supplying the remaining energy demand in heating, transport and industry as well as producing district heating and balancing the electricity grid. In doing so a very diverse group of 14 bioenergy fractions are utilised in a range of conversion technologies, as can be seen in figure 4 (DCCCP, 2010; Damsø, 2012: 106ff). Being a flexible and versatile resource, not to mention the only remaining fuel, biomass is a key component in solving the supply task of a 2050 decarbonised energy system (Slade et al., 2010). The target state and energy transition sections outline overall pathways towards a self-sufficient renewable energy supply in 2050 and indicate key policy targets and priorities. Following the formulation of an energy transition pathway, concrete policy actions can be formulated in the short term and

evaluated based on their contribution to the targeted development.

5. Implications for Energy Planning

The case study of the Region of Zealand point to some aspects of the planning environment that have implications for the energy-planning task ahead. The long lead and life times of energy infrastructure has a tendency towards technological lock-in. The energy system is characterized by a high capital intensity, longevity and fuel specificity for most of the capital assets in a given energy system (Scrase & MacKerron, 2009: 95). Put simply, this means that a facility will usually have a lifetime of 20-50 years, and once built it is not easily converted. This means that many of the current assets must be a part of the future supply system in the medium term, and many assets constructed in the near future will still be part of the system in 2050. This underlines the need for long-term planning, to ensure that facilities constructed today can actually form a part of the future system. This strategy is however challenged by the complexity and uncertainty characterising the problem at hand (Head, 2008: 103). Looking into the concept of uncertainty we can distinguish between uncertainty due to variability and uncertainty due to limited knowledge. The first group comprises, among others, unforeseen technological changes, behavioural and societal variability as well as if policies do not have the expected effect; whereas in the latter, uncertainty relates to inexactness, indeterminacy and ignorance (Mander et al., 2007: 26f). One of the key characteristics of energy planning is the fact that numerous categories of this uncertainty taxonomy are touched upon simultaneously. On the one hand several aspects of the coming transition, such as the technological development, are unknowable, however at the same time there is only a limited capacity among planners to obtain knowledge as well, making inexactness and ignorance an unavoidable part of planning.

Planning in these circumstances is a difficult task, and without the aid of proper planning tools an impossible task. Simplification is a necessary tool when working with highly complex contexts, and proper use of the 'macroscope' in limiting the myriad of details to see the big picture can lead to significant insights (Odum, 2007: 2f; Hansen, 2007: 27). However this simplification is very often utilized in developing models for forecasting, and when

subsequently predicting the future and prescribing policy adaptations the simplifications, assumptions and adaptations tend to be forgotten, leading to the fallacy of misplaced concreteness (Hansen, 2007: 27; Robinson, 1982b: 233). Or as put by William Sherden *“So long as we do not question the validity of forecasts and think for ourselves, we will be destined to be deluged by a constant reign of error from those dismal scientists [...] ever eager to fill our need for prediction.”* (quoted in Pilkey & Pilkey-Jarvis, 2007:186). Additionally forecasting is inevitably conservatively biased, as it is necessarily based on past trends (Robinson, 1982b: 232). As such applying it in planning for an energy transformation is problematic. As renewable energy must progress from the current level of supply to completely supplying the energy system, the way of conceiving renewable energy must develop as well, from a focus on diffusion and integration to one of viewing a system based on renewable sources of energy. The approach applied in this article is based on the planning principles of working systemic and target-oriented, and does so by utilizing backcasting as a planning framework. In doing so simplification will be guided by the target of a future renewable energy system, thereby minimizing the risk of ignoring key aspects of the transitional chain.

However a backcasting based transitional plan is not necessarily easily transferable to concrete action planning in the short term. Addressing the task of formulating action plans in short-term planning (e.g. 2020 plans) in relation to the backcasted pathway, the case study points to another key concept: The aspect of flexibility. The combination of long infrastructural life times and high uncertainty with regards to technological development, creates a necessity for introducing a high degree of flexibility, or robustness, into the plan. Flexible capacity is a key analytical tool in many planning environments, with terms such as liquidity, versatility, resilience and hedging all being terms aimed at achieving it (Rosenhead, 2001: 187f). The key aspect of robust decision making is that it strives for robustness rather than optimality, aiming for a system that performs satisfactory under a range of uncertain futures, rather than performing optimally for a few scenarios (Matrosov et al., 2013: 43). Ensuring flexibility in a plan implies developing a plan that could be compatible with several different visions of the future, using equipment that can form part of several possible

system choices (Crossley & Sørensen, 1983: 17). A key tool in doing so involves distinguishing between decisions and plans. A decision is a commitment of resources, whereas a plan is a foreshadowing of anticipated future decisions, which can be revised in light of new knowledge (Rosenhead, 2001: 186f). In this way making decisions that keep attractive future options open, and subsequently respond to new situations by adapting the plans would be the optimal way of addressing uncertainty in the planning environment (Rosenhead, 2001: 181; Hassnoot et al., 2011: 485). As such, planning in the short term should not only be in the form of steps towards the target state through the outlined transitional pathways, but also ensure a high degree of flexibility to hedge against uncertainty. In the case study, this has been done through the use of sequential decisions, or phased expansion in which e.g. hybrid cars are used to initiate change towards electric infrastructure, but keep the option of a fuel based approach open. Similarly, district heating expansion is conducted through constructing small collective heating systems based on large heat pumps, and subsequently connecting these into larger district heating systems as appropriate, and natural gas fired combined heat and power plants are used to expand decentralized plants to balance electricity production, which can then subsequently be converted from natural gas to biomass based gas. In this way, the plan is embedded with possible turning points where decisions can be reversed in light of new information on technology development.

6. Conclusion

Planning for a transition to renewable energy warrants a systemic and target-oriented approach to planning. In this article a backcasting-based approach is proposed, presented and applied to a case study of the Danish Region of Zealand. The analysis points to key aspects of a system based on local renewable energy resources in 2050 and develops a transitional pathway towards it. In subsequently formulating short-term action plans, we should ensure a high level of flexibility as the task at hand is challenged by long lead and life times of energy infrastructure as well as a high degree of uncertainty with regards to technological development. Planning towards the target state, while acknowledging and hedging against uncertainty can be a key tool in developing more robust and applicable action plans.

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Rikke Lybæk and Jan Andersen have delivered very valuable insights and guidance on the Master's thesis this article is partially based on. The title is with reverence inspired by Steven Spielberg's movie trilogy of the same name (1985, 1989, 1990). The title is with reverence inspired by Steven Spielberg's movie trilogy of the same name (1985, 1989, 1990). Additionally the energy planners in the Region of Zealand and its 17 associated municipalities have been very generous with their time and data. The usual disclaimers apply.

Note

- 1 A more thorough presentation of the case study is available in Damsø, 2012 (in Danish).

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